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The role of temperament in the relationship between early onset of tobacco and cannabis use: The TRAILS study

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ABSTRACT

Background: While temperamental characteristics have been related to the onset of cannabis use, it is not clear at what point(s) along the trajectory from early onset of tobacco use (EOT) to early onset of cannabis use (EOC) these characteristics exert their impact. This study examined if (1) temperamental characteristics predispose to EOT that on its turn predisposes to EOC, and (2) temperament moderates the importance of EOT on the progression to EOC.

Methods: Data from 1848 (83%) participants in the TRacking Adolescents' Individual Lives Survey (TRAILS), a prospective population study of Dutch adolescents, were analyzed. We used parent-reports on the Early Adolescent Temperament Questionnaire to assess the dimensions of high-intensity pleasure, frustration, effortful control, shyness and fearfulness at age 10–12. EOT and EOC were defined as use at least once before the ages of 12 and 13 years, respectively, assessed by means of self-reports. We performed mediation and moderation analyses in Mplus.

Results: High levels of high-intensity pleasure predisposed to entrance in the trajectory from EOT to EOC. Once tobacco use had been initiated at early age, low levels of shyness and high levels of high-intensity pleasure increased the risk of progression to EOC.

Conclusions: Besides a common liability for EOT and EOC based on temperament, the risk of transition from tobacco to cannabis use is modified by temperamental characteristics. Differences in interplay with other risk factors may explain the impact of temperament on distinct points along the substance use trajectory.

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1. Introduction

The use of cannabis has been associated with various risks, especially for adolescent users (Arseneault et al., 2002; Lynskey and Hall, 2000). Particularly adolescents who initiate cannabis use before the age of 13 may be at risk for adverse substance use outcomes (Kandel et al., 1986; Robins and Przybeck, 1985). These adolescents are characterized by relatively low scores on school performance and commitment, parent–child relationship, and peer-pressure resis-

tance when compared to late-onset and non-users (Flory et al., 2004). More insight into the mechanisms behind early initiation of cannabis use would contribute to the identification of at-risk individuals and provide better entry points for health promotion interventions.

Legal substance use has been found to predict cannabis use (Guxens et al., 2007; Korhonen et al., 2008; McCambridge and Strang, 2005). The exact sequence of the use of specific substances, as well as the impact of these substances on the use of other substances, has been a source of debate (Agrawal and Lynskey, 2009; Kandel et al., 2006; Patton et al., 2005). The most likely sequence is from legal to semi-legal or illegal substances, as access to legal substances is generally easier compared to access to cannabis or other illicit drugs in adolescence. Previous research has indicated that particularly cigarette smoking, rather than alcohol use, is associated

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with elevated odds of subsequent cannabis use (Korhonen et al., 2008). Moreover, early initiators of cigarette smoking have a particularly high risk for subsequent use of cannabis (Golub and Johnson, 2001; Kandel and Yamaguchi, 1993; Korhonen et al., 2008).

As yet, little is known about the mechanisms underlying the progression from onset of cigarette smoking to cannabis use. More specifically, one undetermined aspect is the role of temperamental characteristics in this sequence. While personality and temperamental characteristics have been related to the onset of either cigarette smoking or cannabis use in adolescence (Harakeh et al., 2006; Wills et al., 2001), it is not clear at what point(s) along the trajectory towards onset of cannabis use these characteristics are influential. Based on the common liability model, which suggests a common underlying factor for use of various substances, one would expect that the same temperamental characteristics predispose to onset of both cigarette smoking and cannabis use. Thus, given the most frequent developmental sequence of drug involvement, these temperamental characteristics would predispose to early tobacco use and subsequently to experimentation with cannabis as opportunities arise. However, the common liability model does not explain why some early tobacco users do not progress to early experimentation with cannabis. Moreover, it remains undetermined whether temperamental characteristics affect the risk of transition to cannabis use once the chain of substance use has been initiated.

When temperament is studied in relation to substance use, specific aspects of temperament, instead of general concepts, have often been used. First, indicators of sensation seeking, manifested in frequent exploratory activity, intense reactions to reward and difficulty inhibiting behavioral impulses, has been found to predict onset of cannabis use in adolescence (for a review see Creemers et al., *in press*). In addition, negative affectivity or negative emotionality, reflecting the tendency to easily become frustrated and irritated and to become intensely upset, has been associated with substance use (Wills et al., 2001). A dimension often termed task orientation, attentional control or effortful control, which reflects the ability to regulate attention and behavior and to follow through to completing the task, has been related to a lower likelihood of substance use (Wills et al., 2001).

Using data from the TRacking Adolescents' Individual Lives Survey (TRAILS), a general population study, we investigated the roles of temperamental characteristics in the relationship between early onset of cigarette smoking and early onset of cannabis use. Strengths of the TRAILS study are that information about its participants is gathered from multiple informants, and the possibility to control for important correlates, such as alcohol initiation, parental licit substance use, and parenting factors. Aims of the present study were to examine (1) the risk of transition from early onset of tobacco use (EOT) to early onset of cannabis use (EOC), (2) whether temperamental characteristics that predict EOC first predispose to early cigarette smoking that subsequently predicts EOC (mediation), and (3) whether temperament modifies the risk of transition from EOT to EOC (moderation).

2. Methods

2.1. Sample and participants

The present study reports data from the first (T1) and second (T2) assessment waves of the TRAILS, which ran from March 2001 to July 2002 and from September 2003 to December 2004, respectively. A detailed description of the sampling procedure and methods is provided in De Winter et al. (2005). Briefly, the TRAILS target sample involved all 10–11-year-old children living in five municipalities in the North of the Netherlands, including both urban and rural areas. The sample selection involved two steps. First, the selected municipalities were asked to provide names and addresses of all inhabitants born between October 1, 1989 and September 30, 1990 (first two municipalities) or October 1, 1990 and September 30, 1991 (last three municipalities). Second, primary schools (including schools for special education)

within these municipalities were simultaneously approached with the request to participate. School participation was a prerequisite for eligible children and their parents to be approached by the TRAILS staff. Of all the selected inhabitants ($n = 3483$), 90.3% attended a school that was willing to participate ($n = 3145$). 6.7% were excluded because of incapability or language problems. Of the remaining 2935 children, 76.0% ($n = 2230$, mean age = 11.09, $SD = 0.55$, 50.8% girls) were enrolled in the study (i.e., both child and parent agreed to participate). Responders and non-responders did not differ with respect to the prevalence of teacher-rated problem behavior nor the associations between sociodemographic variables and mental health indicators (De Winter et al., 2005).

Of the 2230 T1 participants, 96.4% ($n = 2149$, 51.2% girls) participated in T2, which was held 2–3 years after T1 (mean interval 29.4 months, $SD = 5.4$). The mean age at T2 was 13.55 years ($SD = 0.54$). For the analyses of the present study, subjects who reported EOC before EOT were excluded from the analyses ($n = 5$). Only subjects were included of which complete data on temperament, onset of cigarette smoking and onset of cannabis use were available ($n = 1848$). The participants included in the current study had a somewhat higher intelligence (see below for more details) ($t = 6.68$, $df = 2228$, $p < 0.001$), a higher socioeconomic status ($\chi^2(2, n = 2188) = 69.20$, $p < 0.001$), and were less likely to have a family history of substance abuse or antisocial behavior ($t = -2.61$, $df = 2163$, $p < 0.01$), when compared to the excluded subjects.

2.2. Measures

2.2.1. Temperament and substance use

Early adolescent temperament was assessed at T1 by the parent version of the short form of the Early Adolescent Temperament Questionnaire—Revised (EATQ-R) (Putnam et al., 2001), preferably completed by the mother. The Dutch version of the EATQ-R identifies 6 temperament dimensions and 2 behavioral dimensions (Oldehinkel and Hartman, 2003). Of interest for the present study were the dimensions (1) high-intensity pleasure, defined as the pleasure derived from activities involving high intensity or novelty (6 items, $\alpha = 0.77$), (2) frustration, defined as negative affect related to the interruption of ongoing tasks or blocked goals (5 items, $\alpha = 0.74$), (3) shyness, referring to behavioral inhibition to novelty and challenge, especially social (4 items, $\alpha = 0.84$), (4) fearfulness, manifested in worrying and unpleasant affect related to the anticipation of distress (5 items, $\alpha = 0.63$), and (5) effortful control, defined as the capacity to voluntarily regulate behavior and attention (11 items, $\alpha = 0.86$). For the dimensions high-intensity pleasure and frustration we expected that high levels on these measures would be associated with a higher risk of early onset of cannabis use. For the dimensions effortful control, shyness and fearfulness we expected a negative association with early onset of substance use. Factor analyses show that these measures are statistically distinct and that the risk and protective factors are inversely but not strongly correlated (ranging from 0.05 to 0.40).

Tobacco and cannabis use were assessed at T1 and T2 by self-report questionnaires filled out at school, supervised by TRAILS assistants. Confidentiality of the study was emphasized. At T1, adolescents were asked in separate questions whether or not they had ever used tobacco or cannabis. At T2 they were asked to report the age of onset (in years) of any tobacco and cannabis use. EOT was defined as onset of use before the age of 12 years (Vega and Gil, 2005). EOC was defined as onset of use before the age of 13 years (Hawkins et al., 1992; Kandel et al., 1986; Robins and Przybeck, 1985). Although the reliability of self-reports on substance use has been a subject of debate, previous research has concluded that, when anonymity is assured, self-report measures of substance use have acceptable reliability (Murray and Perry, 1987).

2.2.2. Confounding variables

Intelligence was individually assessed at T1 by the Vocabulary and Block Design subtests (Sattler, 1992) of the Revised Wechsler Intelligence Scales for Children (WISC-R) (Van Haasen et al., 1986; Wechsler, 1974).

Lifetime alcohol consumption was assessed at T1 by self-reports. Responses were dichotomized into never and ever lifetime alcohol intake.

Perceived parental emotional warmth was assessed with the EMBU-C (Markus et al., 2003), the child version of the EMBU (a Swedish acronym for My Memories of Upbringing, developed by Perris et al., 1980). The scale of emotional warmth contains 18 items ($\alpha = 0.91$ for both parents). Because the associations for father and mother were high ($r = 0.79$, $p < 0.001$) we combined them into a single measure, which was based on only one informant when information from one parent was missing.

Parental substance use was assessed during the parental interview at T1. In most cases, mothers were asked about their own and their partners' cigarette smoking and alcohol use. For both parents, responses were categorized into low (smoking less than daily and drinking less than one glass a week), moderate (smoking 1–9 cigarettes a day or 1–10 drinks a week), and high parental substance use (smoking 10 or more cigarettes a day or drinking 11 or more drinks a week). Maternal and paternal scores were combined and divided by two to achieve an average score of parental substance use. When information on one parent was missing this composite score was based on only one informant.

Socioeconomic status (SES) was calculated as the average of income level, educational level, and occupational level of each parent at T1, using the International Standard Classification for Occupations (Ganzeboom and Treiman, 1996), and was categorized into low, average and high SES.

Pubertal development at T1 was based on parent ratings on schematic drawings of secondary sex characteristics associated with the five standard Tanner stages of pubertal development (Marshall and Tanner, 1969). Tanner stages are a widely accepted standard for assessment of physical development, and have demonstrated good reliability, validity and parent–child agreement (Dorn et al., 1990; Marshall and Tanner, 1969). Children were classified into five stages of puberty, in which stage 1 corresponds to infantile and stage 5 to complete puberty (Tanner and Whitehouse, 1982).

2.3. Statistical approach

Statistical analyses were performed using the Statistical Package of Social Sciences version 15.0 for Windows (SPSS Inc. Chicago, IL) and Mplus 5.1 (Muthén and Muthén, 1998–2007). Temperamental scale scores were standardized to a mean of 0 and a standard deviation of 1. Means of variables and correlations between them were calculated, and gender differences in means and proportions were analyzed by *t*-tests and χ^2 -tests, respectively. All paths towards EOC were adjusted for sex, pubertal development, intelligence, SES, parental substance use, and perceived parental emotional warmth. When EOT was included as a predictor of EOC, we additionally adjusted for alcohol initiation. In order to make the final model as parsimonious as possible we excluded all non-significant covariates. Model fit was determined using the comparative fit index (critical value = 0.95) and the root mean square error of approximation (critical value = 0.08) (Bentler, 1990; Brown and Cudeck, 1993).

First, we conducted logistic regressions to address the risk of EOC in early onset cigarette smokers, as compared to never smokers.

Second, we assessed whether the relationship between temperamental characteristics and EOC was mediated by the influence of temperament on EOT. We started with separate regression analyses with each of the standardized temperamental scale scores as the predictor and EOC as the outcome. To assess the independent influences of each of the temperamental characteristics, we specified a model including all significant temperamental scale scores. The final model included only the temperamental characteristics that remained significant. We included the significant predictors together with EOT in an additive model to test the independent effects of the various predictors. In order to test mediation, we first specified a direct model, in which EOC was regressed on the temperamental characteristics of the final model, in addition to regressing EOT on these characteristics. This was done to ascertain that direct effects of the same temperamental characteristics to both EOT and EOC were present. Both paths were adjusted for all aforementioned covariates except alcohol initiation. We then specified a full mediation model by allowing for the direct path of EOT to EOC, additionally adjusting for alcohol initiation. To test for an indirect effect from temperament to EOC via EOT, a joint significance test of the indirect paths was used (Baron and Kenny, 1986; MacKinnon et al., 2002; Sobel, 1982). In order to determine whether the mediation model was a better representation of the data when compared to the final additive model, model fit was compared using the Chi-square difference tests for weighted least squares means and variance adjusted (WLSMV) and maximum likelihood means and variance (MLMV) adjusted estimation (Muthén and Muthén, 1998–2007).

Finally, we tested whether temperament modified the transition from EOT to EOC. We specified separate logistic regression models for each of the temperamental scale scores, in combination with EOT, and the interaction between the two. To control for the possibility that associations between temperament and cannabis use were spurious due to a shared link with tobacco use, tobacco use was added as an outcome variable (multivariate logistic model) that was regressed on the same temperamental scale score. To facilitate the interpretation of the significant interaction effects, we performed descriptive analyses to assess the proportion of early initiators of cannabis use in subgroups based on temperament and early onset of tobacco use.

3. Results

3.1. Risk of early onset cannabis use in early onset smokers

18.9% ($n = 350$) of the participants fulfilled the criteria for early onset of tobacco use and 2.8% ($n = 52$) reported early onset of

cannabis use. Percentages or mean scores of the variables, and gender differences in percentages and means are shown in Table 1. Correlations between the variables are shown in Table 2.

As expected, adolescents who reported early onset of tobacco use were more likely to have initiated the use of cannabis at an early age (OR = 4.14, 95%CI = 3.03–16.28, $p < 0.001$). When EOT was included as a predictor, the covariates intelligence, alcohol initiation, SES, parental substance use, and perceived parental emotional warmth were not significantly related to EOC. Therefore, the most parsimonious model included only sex and pubertal development as covariates. A non-significant sex by EOT interaction ($p = 0.81$) indicated that there was no difference in risk of transition between boys and girls.

3.2. Is the relationship between temperament and early onset cannabis use mediated by early onset of tobacco use?

We carried out separate regression analyses to assess the associations between temperamental characteristics at age 10–12 and EOC. When adjusted for the significant covariates sex, pubertal development and perceived parental emotional warmth, high-intensity pleasure significantly predicted EOC (OR = 1.22, 95%CI = 1.05–1.41, $p < 0.01$). Although a low level of shyness was a nearly significant predictor of EOC (OR = 0.86, 95%CI = 0.74–1.01, $p = 0.06$), this effect was attenuated when the independent effects of high-intensity pleasure and shyness were assessed in an additive model, indicating only an independent effect of high-intensity pleasure. None of the other temperamental characteristics was significantly related to EOC. Non-significant sex by temperament interactions (all p -values > 0.46) indicated that there were no differences between boys and girls pertaining to the influence of temperamental characteristics on early onset of cannabis use.

Subsequently, we included high-intensity pleasure and EOT in an additive model. In this model, high-intensity pleasure was no longer a significant predictor of EOC (OR = 1.18, 95%CI = 0.99–1.41, $p = 0.07$), while EOT remained a significant predictor (OR = 4.10, 95%CI = 2.97–5.64, $p < 0.001$). The change in significance of high-intensity pleasure indicated a certain degree of overlap between the predictors.

In order to test mediation, we regressed EOC on high-intensity pleasure in addition to regressing EOT on high-intensity pleasure. This was done to ascertain the presence of a direct effect between high-intensity pleasure and EOT. As can be seen in Table 3, high-intensity pleasure was significantly associated with EOT. When the direct path from EOT to EOC was allowed, findings showed that the relationship between temperament and EOC was completely mediated by EOT, rendering the direct effect of high-intensity pleasure non-significant. The fit indices for this model were comparative fit index (CFI) 0.99 and root mean square error of approximation (RMSEA) 0.02. Chi-square difference testing indicated that fit of the mediation model was significantly better when compared to the fit of the additive model ($\chi^2(1) = 11.39$, $p < 0.001$).

Table 1
Descriptive statistics of the TRAILS sample.

| | Boys ($n = 900$) | Girls ($n = 948$) | Gender difference | | |
|----------------------------|--------------------|---------------------|-------------------|-------------------|-------|
| | Mean (SD) | Mean (SD) | t/χ^2 | df | p |
| Tobacco use before age 12 | 19.7% | 18.2% | 0.60 | 1 | 0.44 |
| Cannabis use before age 13 | 3.8% | 1.9% | 5.96 | 1 | <0.05 |
| High-intensity pleasure | 3.43 (0.92) | 3.21 (0.92) | 5.12 | 1846 | <0.01 |
| Frustration | 2.84 (0.68) | 2.75 (0.64) | 2.92 | 1822 ^a | <0.01 |
| Effortful control | 3.10 (0.69) | 3.35 (0.65) | −7.96 | 1823 ^a | <0.01 |
| Shyness | 2.41 (0.88) | 2.59 (0.87) | −4.30 | 1846 | <0.01 |
| Fearfulness | 2.34 (0.69) | 2.49 (0.75) | −4.42 | 1846 | <0.01 |

^a Degrees of freedom not equal to $n - 1$ due to the correction for unequal variances.

Table 2

Correlation matrix of T1 temperament, early onset of tobacco use and early onset of cannabis use.

| | 1 ^a | 2 ^a | 3 | 4 | 5 | 6 |
|-------------------------------|---------------------|----------------|---------|---------|---------|--------|
| 1. Tobacco use before age 12 | | | | | | |
| 2. Cannabis use before age 13 | 0.29** ^b | | | | | |
| 3. High-intensity pleasure | 0.10** | 0.07** | | | | |
| 4. Frustration | 0.09** | 0.04 | −0.01 | | | |
| 5. Effortful control | −0.13** | −0.05* | 0.05* | −0.40** | | |
| 6. Shyness | −0.07** | −0.06* | −0.29** | 0.09** | −0.02 | |
| 7. Fearfulness | 0.03 | 0.03 | −0.19** | 0.31** | −0.24** | 0.14** |

^a Point biserial correlations for associations between a continuous and a dichotomous variable.^b Tetrachoric correlation.* $p < 0.05$.** $p < 0.01$.**Table 3**

Final mediation model.

| Predictor | Outcome | Step 1 | | Step 2 | |
|-------------------------------------|---------|------------|-----------|------------|-----------|
| | | Odds ratio | 95%CI | Odds ratio | 95%CI |
| High-intensity pleasure | EOT | 1.17*** | 1.09–1.25 | 1.13*** | 1.05–1.21 |
| High-intensity pleasure | EOC | 1.22* | 1.05–1.43 | 1.10 | 0.94–1.27 |
| EOT | EOC | | | 2.02*** | 1.82–2.23 |
| High-intensity pleasure → EOT → EOC | | | | 1.09** | 1.03–1.15 |

Step 1 refers to a direct model in which early onset tobacco use (EOT) and early onset cannabis use (EOC) were regressed on high-intensity pleasure. In the final model, EOC was adjusted for sex and pubertal development; EOT was adjusted for pubertal development, intelligence, SES, parental substance use, and perceived parental emotional warmth.

Step 2 refers to a full mediation model that allowed for an additional direct path from EOT to EOC. In the final model, EOC was adjusted for pubertal development, EOT was adjusted for intelligence, initiation of alcohol use, SES, and perceived parental emotional warmth.

All continuous variables were standardized to mean zero and standard deviation 1.

CI = confidence interval.

* $p < 0.05$.** $p < 0.01$.*** $p < 0.001$.

3.3. Does temperament modify the risk of transition from early onset of tobacco use to early onset of cannabis use?

Findings of the temperament by EOT interactions indicated that the levels of high-intensity pleasure ($OR = 1.48$, $95\%CI = 1.03–2.12$, $p < 0.05$) and shyness ($OR = 0.61$, $95\%CI = 0.41–0.92$, $p < 0.05$) modified the risk of transition from EOT use to EOC. Whereas main effects of EOT remained significant, there were no main effects of temperament. The fit indices indicated almost sufficient fit for the model with high-intensity pleasure ($CFI: 0.92$, $RMSEA: 0.06$) and shyness ($CFI: 0.88$, $RMSEA: 0.07$) as moderating variables. None of the other temperamental scales modified the risk of transition from EOT to EOC. Three-way temperament by EOT by sex interactions indicated no significant gender differences (all p -values > 0.28).

To facilitate the interpretation of the interaction effects, we performed descriptive analyses in order to assess the proportion of early initiators of cannabis use in subgroups based on high and low levels of high-intensity pleasure and shyness, and on EOT-status. Findings are presented in Fig. 1, and indicate that the risk of transition from EOT to EOC was higher in adolescents with low levels of shyness and high levels of high-intensity pleasure when compared to adolescents with opposite levels on these temperamental constructs.

4. Discussion

The findings of the present study indicate that the risk of EOC was more than four times as high in individuals who initiated the use of tobacco at an early age when compared to individuals who did not smoke cigarettes this early in life. This finding is in line with results of previous studies that found a higher incidence of cannabis use among early initiators of tobacco use (Golub and Johnson, 2001;

Kandel and Yamaguchi, 1993; Korhonen et al., 2008), and indicates that the onset of smoking before the age of 12 signals an increased risk of entrance into a sequence of adverse behaviors.

By means of mediation and moderation models we investigated at what point(s) along the trajectory from EOT to EOC temperamental characteristics exerted their impact. Results from our mediation analyses suggest a common liability for tobacco and cannabis use with regard to the temperamental dimension high-intensity pleasure. A high level of high-intensity pleasure predisposed to EOT which in turn increased the risk of EOC. While prospective associations between related measures of novelty seeking and either tobacco or cannabis use have been identified before (Mâsse and Tremblay, 1997; Stephenson and Helme, 2006), this is, to the best

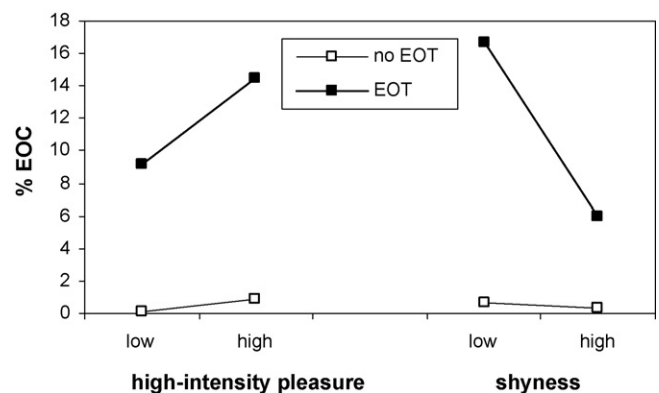


Fig. 1. Graphical presentation of the interactions of either high-intensity pleasure and shyness and early onset tobacco use (EOT) in relation to early onset of cannabis use (EOC).

of our knowledge, the first study that assessed the interrelationship between these factors by applying a mediation model. An indication for some interrelation between sensation seeking and smoking in relation to marijuana use has been provided by [Siqueira and Brook \(2003\)](#). In their study, the odds of daily cigarette smoking in mid-adolescence that predicted marijuana use 2 years later decreased when sensation seeking had been taken into account ([Siqueira and Brook, 2003](#)), indicating some overlap between the constructs.

In addition to illustrating a common liability for EOT and EOC based on a high level of high-intensity pleasure, moderation analyses showed that the levels of high-intensity pleasure and shyness determined the risk of transition from tobacco to cannabis use. When adolescents had used tobacco before the age of 12, high levels of high-intensity pleasure and low levels of shyness were associated with an increased risk of progression to the use of cannabis. Thus, while a high level of high-intensity pleasure predisposes to tobacco use which in turn predisposes to cannabis use, its level also determines one's subsequent risk of making this transition. These common and specific effects might involve differential interplay between high-intensity pleasure and other risk factors of substance use. For instance, high levels of high-intensity pleasure might influence the selection of peers who share risk-taking tendencies, including the use of substances. However, once a substance has been used, high levels of high-intensity pleasure might influence interest in trying other substances of abuse. As expected, low shyness, defined as behavioral inhibition to novelty and challenge, particularly in the social domain, was associated with a higher risk of transition from tobacco to cannabis use. Measures of low behavioral inhibition in late childhood and early adolescence have previously been associated with early onset of cannabis use ([Masse and Tremblay, 1997](#); [Shedler and Block, 1990](#)). However, the observation that not all adolescents with certain temperamental characteristics will initiate the use of substances at an early age, suggests the influence of other factors, such as attitudes towards the use of substances, the presence of behavioral problems, peer use, and family factors. For instance, the findings of [Kellam et al. \(1980\)](#) indicate that whereas moderate or severe shyness was associated with lower cannabis use frequencies 10 years later, it was associated with the highest rate of cannabis use in a subgroup with additionally moderate or severe levels of aggressiveness. We posit that interplay between temperament and other risk and protective factors of substance use might explain our finding that the level of shyness affects the risk of transition from EOT to EOC, rather than the risk of early onset of EOC via EOT.

In our study, fearfulness, frustration, and effortful control were not related to EOC. Whereas the absence of significant findings might be due to the differences in conceptualization of the temperamental constructs when compared to previous studies, and to the relatively low reliability of the subscale fearfulness ($\alpha = 0.63$), it is speculated that the influence of these temperament dimensions might depend on developmental phase and substance use measure. Rather than being associated with early onset of use, fearfulness, frustration and effortful control may affect the risk of regular substance use or abuse.

The present study is not without limitations. First, because of the characteristics of our sample and our focus on EOT and EOC, temperamental characteristics were assessed at or around the same age as early onset of use. Therefore, we were not able to investigate the temporal relation between temperament and onset of cigarette and cannabis smoking. Second, EOT and EOC were based on reported age at onset in years. While we could determine that EOT preceded EOC for the majority of participants, 17 participants reported the same year of onset for both events. Because the use of tobacco generally precedes the use of cannabis, we did not exclude these participants from our analyses. As a consequence, some participants that used

cannabis before the use of tobacco, albeit in the same year, might have been included in the sample. Finally, though confidentiality of the study had been emphasized, participants might have underreported their use of cannabis, which may have influenced the results. However, because of the importance of studying adolescent substance use, our results contribute to understanding the mechanisms underlying early onset of cannabis use in a general population of adolescents.

In conclusion, our findings indicate that high levels of high-intensity pleasure predispose to entrance and continuation in the trajectory from tobacco to cannabis use and that levels of shyness and high-intensity pleasure determine the impact of EOT on EOC. Besides our specification of the mechanisms by which temperament and smoking interrelate, this paper contributes to the current knowledge due to our focus on characterizing at-risk individuals based on early onset of substance use. Risk-taking behavior, including the use of substances, is inherently related to adolescence because of an increased interest in risk-taking behavior in combination with developing self-regulatory capacities ([Steinberg, 2004](#)). Temperamental factors appear to contribute to the risk of progression from licit to illicit drugs, most likely in interaction with other risk or protective factors. Given the yet immature self-regulatory competence of adolescents, the efficiency of educational interventions in this developmental phase is likely to be limited. It may be more effective to focus on the interplay of temperament and interpersonal characteristics, such as peer influence and parental monitoring ([Hampson et al., 2008](#); [Stephenson and Helme, 2006](#); [von Sydow et al., 2002](#)), and contextual factors that influence the availability of substances.

Conflict of interest

All authors declare that they have no conflicts of interest.

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Contributors

Authors Creemers, Korhonen and Huizink designed the study. Statistical analyses were performed by Creemers. Creemers wrote the first draft of the manuscript. Korhonen, Kaprio, Vollebergh, Ormel, Verhulst and Huizink commented on this draft. All authors contributed to and have approved the final manuscript.

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